OPTICAL FIBERS FORMING FOR OPTICAL SENSORS RESEARCH

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Abstract: We present development of new methods and techniques of the splicing and shaping optical fibers with focusing to development new sensors. We developed new techniques of splicing for standard Single Mode (SM) and Multimode (MM) optical fibers and optical fibers with different diameters in the wavelength range from 532 to 1550 nm. Together with development these techniques we prepared other techniques to splicing and shaping special optical fibers like as Polarization-Maintaining (PM) or hollow core Photonic Crystal Fiber (PCF) and theirs cross splicing methods with focus to minimize backreflection and attenuation. Splicing special optical fibers, especially PCF fibers with standard telecommunication and other SM fibers, can be done by light adjustment of our developed techniques.

Development of these new optical fibers splicing techniques and methods are made with respect to using these fibers to another research and development in the field of optical fiber sensors, laser frequency stabilization and laser interferometry based on optical fibers.

Keywords: microstructured fibers, optical sensors, shaping optical fibers, splicing optical fibers, tapering optical fibers.

1 INTRODUCTION

Fiber optic sensors are most widely used in the last two decades. The most used types of the fiber optic sensors are sensors with fiber Bragg grating (FBG). They are used in many industry fields such as telecommunications, aero industry, hydro or nuclear turbines, cars, planes [1], ships [2], railways, roads to oil and gas wells. One of the most progressing fields in the utilization of FBG sensors are structural health monitoring (SHM) systems [3]. The SHM systems are a fundamental tool to control state and lifetime of any structures such as tunnels, bridges, dams, nuclear power plants and other special and critical structures. The SHM systems can record, analyze, localize, and predict the state of the structures by non-destructive methods [4].

Other types of sensors can use principles of optical resonators in fibers, known as Raman scattering or Brillouin scattering, etc. One of the new and perspective principle of optical fiber sensors are microstructured fibers, which can be basically divided into the fibers with solid core known as a Photonic Crystal Fibers (PCF) and the fibers without solid core known as Photonic Bandgap Fibers (PBGF). In the sensor technology, PC fibers can be used to measure gases and liquids by the methods based on the measurement of refraction index changes through the fiber. By writing FBGs into the PCF [5] can be improved theirs properties and theirs usability can be extended. On the other side the PBGF can be used to measure the concentration of gases and the liquids by measurement of the change of the optical power at the end of the fiber [6].

In comparison with standard electrical sensors, the optical fiber sensors have many advantages. They have compact size, better chemical resistance, they are immune to electromagnetic field and they have ability to measure over a long distance without electricity. These advantages predetermine the optical fiber sensors for extensive field of applications.

Adequate preparation of the optical fibers is essential to any successful application; the optical fiber with FBG sensors had to be nitrogen loaded to writing FBG, optical fibers to vibration sensors with FBG [7] had to be shaped, gas or spectroscopic sensors in microstructured fiber had to be spliced to standard telecommunication fibers, optical fibers designed for measuring ionizing radiation have to be etched. Our research presents the preparation of the optical fibers for further use with specific sensors.

2 OPTICAL FIBERS FORMING

Optical fiber forming consist shaping optical fibers, closing PC fibers and splicing nonstandard fibers with standard fibers. These forming of optical fibers can be used to design new sensors, to improve standard optical sensors and to improve usability of optical fibers in other fields of applications. More information on the theory of optical fiber forming was presented [8].

We present our results of the optical fibers forming, especially shaping, splicing and etching standard and special optical fibers. We used the Arc Fusion Splicer FSM 100P which can splice optical fibers with cladding diameter of 60 to 500 μm, and maximum optical fiber sweep length of ± 5 mm. The splicer has two sets of programs. Standard program of splicing is used to splicing single mode optical fibers, multimode optical fibers, and polarization optical fibers. On the other side the special program can be used to realization splicing SMF with PCF, tapering standard optical fibers, closing and shaping optical fibers, creating of optical lens at the end of the fiber etc. We have started to test settings necessary for the process of splicing microstructured and other optical fibers and preparation of the etched fibers to develop ionizing radiation optical fiber sensor.

2.1 SHAPING OF STANDARD OPTICAL FIBER

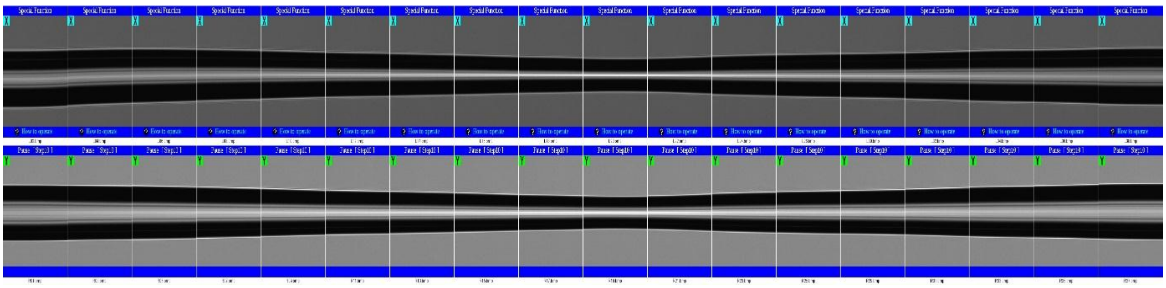
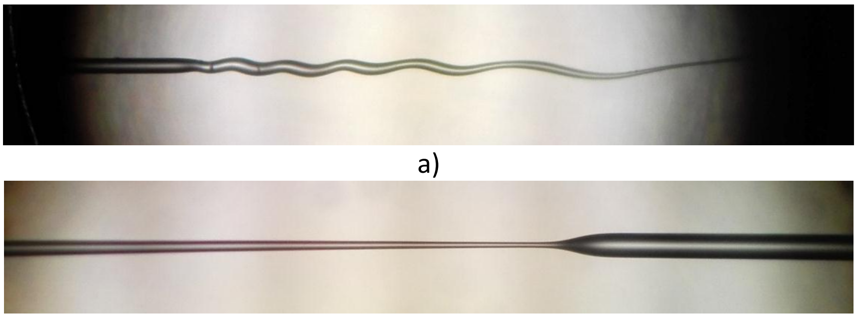


Figure 1: Taper of the standard optical fiber – length of tapered part is 3 mm; the smallest diameter is 90 μm. X and Y view from the fiber splicer.

We tested realization of several types of tapers from short (abrupt) to long (up to ten millimeters). One of the first short optical fiber tapers is in the Fig. 1. The diameter before tapering of optical fiber is 125 μm and after tapering is 90 μm in the narrowest diameter of the taper and the length of taper is 3 mm.

We realized asymmetric long taper with respect to splicing fibers with different core diameters. The splicing optical fibers with different core diameters is better when the cores of the optical fibers have almost the same diameters and the taper should be the same as we planned. In this case we tried to make a taper with fluently decreasing of a diameter without any defects. In the Fig. 2, can be seen an improvement in the realization process of the long taper preparation. In the Fig. 2a is a long taper with unadjusted set of process parameters of the tapering. In the Fig. 2b is a long taper realized by an adjusted process with better process parameters of the tapering.



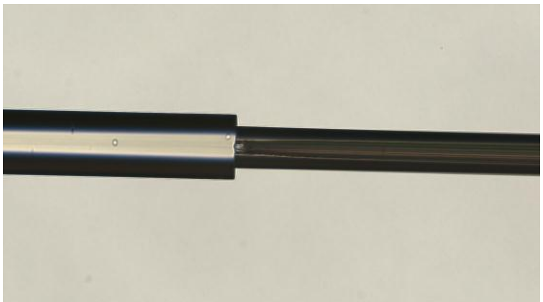
a)

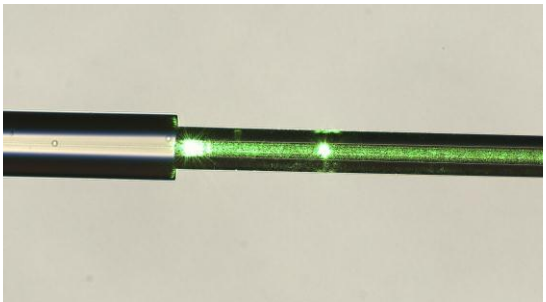
b)

Figure 2: Improvement of the long tapering optical fiber process. Photo of realized long tapers of 8 mm and the smallest diameter of 30 μm. a) unadjusted set of tapering process parameters b) adjusted set of tapering process parameters.

2.2 SPLICING PCF TO SMF

In the next part, we focused on splicing standard optical fibers with microstructured optical fibers for the wavelength 532 nm with different mode field diameters. The optical fiber HCPCF – 532 nm has a cladding diameter of 81 μm, core diameter of 4, 8 μm and the diameter of the microstructure around the core is 23 μm. On the other side the standard optical fiber for wavelength 532 nm (SMF – 460 HP) has cladding diameter 125 μm and core diameter 4, 8 μm. Splicing of these fibers has many degrees of the splicing parameters setting but the key problems of the perfect splice realization are two. The perfect splice means really low attenuation in the propagation axis and the high attenuation of the backreflections. First splicing problem is the basically setting of the positions spliced fibers centers on the ideal position in Arc Fusion Splicer. The second is looking for the optimal distance between centered centers of the splicing optical fibers. The optimal distance of splicing optical fibers is important with respect to bond strength. In compare with splicing HCPCF 1550 [8] is also used less energy and time of electric arc. It is in coincidence with amount of materials in splicing optical fibers. In the case of using more power or more time of the electric arc, the structure in microstructured photonic crystal fiber collapse. After finding optimal program settings of Splicer we achieved attenuation of splicing optical fibers under 2, 6 dB. The photo of splicing different diameter optical fibers is in the figure 3a). The Figure 3b) shows parts of the same fiber where part of optical beam goes out from the fiber - the light doesn't meet the requirement for light propagation in the optical fiber.





a) b)

Figure 3a: Photo of the splicing HCPCF to SM fiber on 532 nm with different diameter optical fibers. The attenuation of the spicing is under 2, 6 dB.

Figure 3b: Photo of the splicing HCPCF to SM 532 fiber - the brighter place in light is loss on the bond of optical fibers.

2.3 ETCHING OPTICAL FIBERS

For the development of a new ionizing radiation sensor, the optical fiber's sensitivity for binding light from surrounding scintillation material of the optical fiber is crucial. One of the options is cladding optical fiber etch. We etched standard optical fiber by 40% hydrofluoric acid (HF) and we found that the etching speed is 10µm / 6 min. Etched standard optical fiber by 40% hydrofluoric acid is in the Figure 4. The etching rate is dependent on the state of HF.

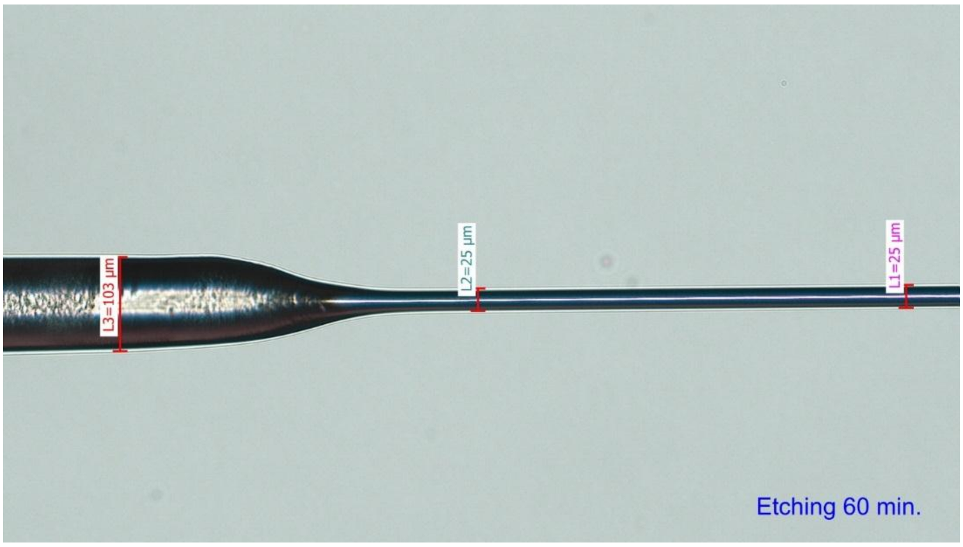


Figure 4: Etched standard optical fiber with 40% hydrofluoric acid.

3 IONIZING RADIATION SENSOR

For measuring ionizing radiation (including x-ray and gamma radiation) we develop an optical fiber sensor. The sensitive part of the ionizing sensor is a scintillation material located at the end of the optical fiber. The scintillation material can be different kind depending on the radiation energy. For the first test we chose the material for x-ray radiation: Gadolinium Oxysulfide doped with Terbium (Gd_2O_2S:Tb) and Yttrium Oxysulfide doped with Terbium (Y_2O_2S:Tb). The emission spectrum of both scintillation materials are about 540 nm. The emission light of material Y_2O_2S:Tb is shown in the Figure 5, where the really low effectivity of the ionizing radiation absorption can be seen.

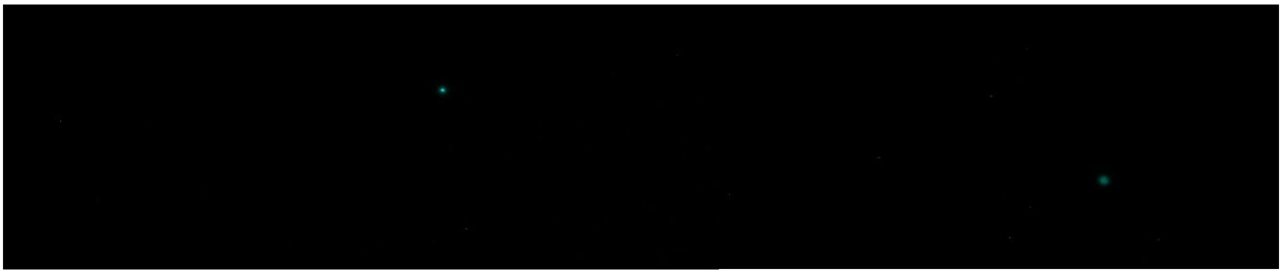


Figure 5: Emission light from scintillation material under ionizing radiation.

4 CONCLUSIONS

We presented the investigation of the parameters of optical fibers forming. The special programs to shaping optical fibers and splicing microstructured optical fibers with standard optical fibers by Arc Fusion Splicer FSM 100P were designed. To develop ionizing radiation optical fiber sensors, the etching optical fibers technology was prepared. We presented our results from our tests and some measurement of achieved parameters. Symmetric and asymmetric optical tapers from fibers with 125 μm diameter was realized. One of the most difficult experiments was splicing Hollow Core fibers with standard optical fibers. Several scintillation materials for ionizing radiation measurement which can be spotted to etched optical fibers were tested. The effectivity of scintillation materials and the bonding of light to the optical fiber will be further tested and improved.

ACKNOWLEDGEMENT

The authors wish to express thanks for support to MEYS CR (LO1212), its infrastructure by MEYS CR and EC (CZ.1.05/2.1.00/01.0017) and by CAS (RVO:68081731). Methods of the shaping and splicing of optical fibers was developed thanks to support from Ministry of Interior of the Czech Republic project no. VI20172020099. The author thanks for support by project no. FEKT-S-17-3934, Utilization of novel findings in micro and nanotechnologies for complex electronic circuits and sensor applications.

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